



THE

PAÑCHASIDDHĀNTIKĀ

THE ASTRONOMICAL WORK

OF

VARĀHA MIHIRA.

THE TEXT, EDITED WITH AN ORIGINAL COMMENTARY IN SANSKRIT
AND AN ENGLISH TRANSLATION AND INTRODUCTION

BY

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PREFACE.

There is some reason to fear that the feeling of any one who may examine in detail this edition and translation of Varâha Mihira's astronomical work will, in the first place, be wonder at the boldness of the editors. I am indeed fully conscious that on the imperfect materials at our disposal an edition in the strict sense of the word cannot be based, and that what we are able to offer at present deserves no other name but that of a first attempt to give a general idea of the contents of the Pañchasiddhântikâ. It would, in these circumstances, possibly have been wiser to delay an edition of the work until more correct Manuscripts have been discovered. Two considerations, however, in the end induced us no longer to keep back the results, however imperfect, of our long continued endeavours to restore and elucidate the text of the Pañchasiddhântikâ. In the first place we were encouraged by the consideration that texts of purely mathematical or astronomical contents may, without great disadvantages, be submitted to a much rougher and bolder treatment than texts of other kinds. What interests us in these works, is almost exclusively their matter, not either their general style or the particular words employed; and the peculiar nature of the subject often enables us to restore with nearly absolute certainty the general meaning of passages the single words of which are past trustworthy emendation. And, in the second place, we feel convinced that even from that part of the Pañchasiddhântikâ which we are able to explain more is to be learned about the early history of Sanskrit Astronomy than from any other work which has come down to our time.

Imperfect and fragmentary as text and translation are, we may assert at any rate that, in our endeavours to overcome the quite unusual obstacles, which the corrupt and bare text of the Pañchasiddhântikâ opposes to the interpreter, we have spared no trouble. The time and thought, devoted to the present volume, would, I may say without exaggeration, have amply sufficed for the editing and explaining of twenty times the amount of text presenting only normal difficulties. This I mention, not of course in order to extol what we have been able to do, but only as an excuse for what we see ourselves obliged to leave undone.

Next to the lamentable state of the text as appearing in the two Manuscripts at our disposal, the greatest disadvantage under which we laboured was the absence of a Commentary. Commentaries can be hardly done without in the case of any Sanskrit astronomical work; much less so, when the text, as that of the Pañchasiddhântikâ, describes many mathematical pro-

cesses more or less diverging from those commonly employed. Commentaries probably existed formerly, and possibly exist even now; but we have failed to procure any. The Commentary published in the present volume is an entirely original composition by my Collaborator. A mere translation of the text with notes would, indeed, have sufficed for the European reader; we however, wished to make the results of our labour accessible to Paṇḍits also who understand no English. And a full *tīkā* giving full demonstrations in the ordinary Hindū style will, in many cases, be useful to the European student also.

The right hand columns of the text give the emended text; the left hand columns the text of the better one of our two Manuscripts which we thought advisable to exhibit in extenso. Some remarks on the Manuscripts and the mode of emendation of the text will be found at the end of the Introduction.

As this preface is signed by myself only, I may, I think, here acknowledge—in a somewhat more explicit way than the mere association of names on the title page is capable of doing—the great obligations under which I am to my collaborator Paṇḍit Mahāmohopādhyāya Sudhākara Dvivedi. His constant assistance was altogether indispensable to me, and all the more welcome as among the Jyautishas of my acquaintance I know of no other, fully equal to work of this kind and at the same time equally ready to devote himself to a task which in certain aspects is so entirely unremunerative. I may express the hope that the Paṇḍit, who is already so well known for his efforts to spread a knowledge of modern higher Mathematics among his countrymen, will continue to devote a part at least of his learning and talents to the elucidation of the ancient history of science in this country.

I further wish to express my best thanks to the Bombay Government and to Professor R. G. Bhandarkar, who with great liberality have allowed me the use, for lengthened periods of time, of all those Manuscripts in their charge which I required for the present edition. Nor must I omit to record my obligations to Professor G. Buehler to whose activity, when in charge of the search for Sanskrit Manuscripts in parts of the Bombay Presidency, we are indebted for the discovery of the two Manuscripts on which this edition is based.

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INTRODUCTION.

The *Pañchasiddhāntikā* by *Varāha Mihira* occupies a marked position of its own in Indian astronomical literature. As a rule works treating of that branch of science claim either to be directly revealed, as *f. i.* the *Sūrya Siddhānta* in that form which has come down to our time; or else to base in all essential points on some older work of divine origin, as *f. i.* the *Siddhāntās* by *Brahmagupta* and *Bhāskarāchārya*, both of which are reproductions, however greatly amplified and improved, of an old *Paitāmaha Siddhānta*. One of the consequences of this is, that these works claim for themselves direct or derived infallibility, propound their doctrines in a calmly dogmatic tone, and either pay no attention whatever to views diverging from their own, or else refer to such only occasionally, and mostly in the tone of contemptuous depreciation. The latter attitude is assumed *f. i.* by *Brahmagupta* who indeed devotes a special chapter to the task of reviewing those astronomical systems which were opposed to the teaching of the *Brahma Siddhānta*, but who would have rendered that part of his work much more valuable and interesting, had he been less anxious to criticize and ridicule than to impart information. The astronomical writers, it is true, therein only exemplify a general mental tendency which displays itself in almost every department of *Hindū Literature*; but mere dogmatic assertion appears more than ordinarily misplaced in an exact science like astronomy, and the absence of all appreciative reference to the views of preceding authors is particularly vexatious, when we have to do with a branch of *Hindū Learning* which shows clear traces of having been remodelled under the influence of Greek teaching.

To the general rule the *Pañchasiddhāntikā* forms a striking exception. As far as we can judge at present, *Varāha Mihira* was the only one among *Hindū* writers on astronomy who thought it worth while to give an exposition of all the more important forms of astronomical doctrine which were current at his time. Not that he was unable to judge of the relative value of the systems which offered themselves to his examination; for, as we shall see further on, he knew very well in what order of merit the five *Siddhāntas* whose teaching he summarizes are to be arranged. But he seems ready to acknowledge that even inferior systems deserve a certain amount of attention, as long as they continue to occupy in certain circles a position of authority; and he appears not to be altogether incapable of taking a purely intellectual interest in examining the various, more or less perfect, methods which may be applied to the solution of scientific problems. At the same time he seems to have no hesitation to acknowledge the connexion of the

modern phase of Hindû astronomy with Greek science. Although directly stating that the Hindûs learned from the Greeks, he at any rate mentions certain facts and points of doctrine which suggest the dependence of Indian astronomy on the science of Alexandria; and, as we know already from his astrological writings, he freely employs terms of undoubted Greek origin. The *Pañchasiddhântikâ* thus becomes an invaluable source for those who wish to study Hindû astronomy from the only point of view which can claim the attention of the modern scholar, *viz.* the historical one.

Regarding its form the *Pañchasiddhântikâ* belongs to the class of so-called *karaṇagranthas* *i. e.* compendious astronomical treatises which do not set forth the theory of the subject at comparative length as the *Siddhântas* do, but merely supply a set of concise—and often only approximately correct—rules which suffice for the speedy performance of all the important astronomical calculations. It however contains a few chapters whose contents lie outside the limits of a mere *karaṇa* and resemble the corresponding chapters of the best known *Siddhântas*; notably the chapter which describes the general constitution of the universe, and the 15th chapter of the *Jyotishopaniṣad*. And it of course decidedly distinguishes itself from ordinary *karaṇas* by the fact that it does not base on any one particular *Siddhânta*, but undertakes to reproduce the more important doctrines of all the different *Siddhântas*.

These five *Siddhântas*, named by Varāha Mihira in the first chapter, are the *Paitāmaha*, *Vāsisṭha*, *Romaka*, *Paulīśa* and *Saura Siddhântas*. Varāha Mihira there also states his view as to their order in importance, assigning the first place to the *Sūrya Siddhânta*, placing next the *Romaka* and *Paulīśa Siddhântas* as about equally correct, and declaring the two remaining works to be greatly inferior to the three mentioned. In agreement with this estimate very different amounts of space are allotted to the individual *Siddhântas* in the body of the work, the *Sūrya Siddhânta* and *Paulīśa Siddhânta* being treated at some length, next to these the *Romaka*, and very little attention being paid to the *Paitāmaha Siddhânta*, and, although this is a somewhat difficult to decide, to the *Vāsisṭha Siddhânta*.

In addition to the general character of the five *Siddhântas*, this difference of treatment is owing to a special cause, mentioned by Varāha Mihira in the first chapter *viz.* his wish to devote the *Pañchasiddhântikâ* chiefly to the task of setting forth the calculation of solar eclipses, the most difficult

I now proceed shortly to discuss the teaching of each of the five Siddhântas as represented by Varâha Mihira. This, however, requires the preliminary settlement of two questions.

In the first place we must attempt to ascertain with accuracy which chapters of the Pañchasiddhântikâ are devoted to each of the five works in question.—This is a task beset by considerable difficulties, as we have no commentary to assist us, and as the indications to be met with in the text as well as in the colophons of the chapters, as exhibited by the two Manuscripts at our disposal, do not, in all cases, enable us to arrive at definite conclusions.

I begin with those chapters, fortunately constituting the majority, which allow themselves to be referred to their respective sources with confidence.—The very short twelfth chapter is, in its colophon, called Paitâmaha Siddhânta, and is in its first stanza declared by Varâha Mihira himself to base on the teaching of Pitâmaha; it is the only chapter in the whole work which is concerned with that Siddhânta.—The eighth chapter treats, according to its colophon, of the calculation of solar eclipses according to the Romaka Siddhânta; and that this really is so, we again have no reason to doubt, as the first stanza refers to the Romaka by name, and as, moreover, the contents of the chapter agree with the statements made in the first chapter about the yuga and the ahargana of the Romaka Siddhânta.—The ninth, tenth and eleventh chapters undoubtedly summarize the doctrines of the Sûrya Siddhânta, as is stated in the colophon, indicated in the first stanza of chapter IX, and borne out by the general agreement of the contents of the three chapters with the Sûrya Siddhânta as known at present. The sixteenth chapter contains, according to the colophon and to stanza 1, the rules of the Sûrya Siddhânta for finding the mean places of the planets; and the seventeenth chapter which teaches how to calculate their true places we may without hesitation refer to the same Siddhânta.

Among the remaining chapters of the work I at first single out those in which Varâha Mihira apparently does not intend to reproduce specific features of one particular Siddhânta, but rather to summarize doctrines held by all the more advanced astronomers of his time, and most probably set forth, with greater or less variations, in three of his five Siddhântas, *viz.*, the Sûrya, Pauliśa and Romaka Siddhântas. To this class of chapters, in which we discern more of the individual Varâha Mihira than in the remainder of the work, I feel inclined to reckon three or perhaps four sections. In the first place the thirteenth chapter, designated in the colophon as 'trailokyasamsthâna', which gives a popular exposition of the sphericity of the earth and the different aspects of the celestial sphere which are due to difference of

terrestrial latitude. The mode of treatment of these questions is no doubt Varāha Mihira's own, as also the interesting criticisms passed on some astronomical schools. In the same way the fourteenth chapter, which is chiefly engaged in showing how certain results may be obtained not only by calculation but more directly by observation and the inspection of certain mechanical contrivances, appears, on the whole, to be Varāha Mihira's own, although the more scientific of his five Siddhāntas no doubt treated of those topics in a similar manner. The same remarks apply to the fifteenth chapter which is even more distinctly individualistic, and contains interesting references to other astronomers. I am more doubtful about the position of chapter IV. which in the colophon is merely counted as such, without any special designation. The matter of the chapter corresponds to what in the best known astronomical works is set forth in the so-called tripraśnādhikāra, with the addition, however, of rules for calculating the table of sines (which ordinarily are given in the spasṭādhikāra). It is not improbable that here also Varāha Mihira sums up, in his own fashion, whatever he found of value in the corresponding chapters of the Romaka, Pauliśa and Sūrya Siddhāntas. On the other hand, as the fourth chapter follows and precedes chapters specially devoted to the Pauliśa Siddhānta, it is not impossible that its contents are meant to sum up the teaching of that Siddhānta only. The decision in this case is however of no very great importance, as the rules given in the fourth chapter on the whole closely agree with the general Siddhānta doctrine.

Among the chapters not yet discussed we first notice the sixth chapter which the colophon states to treat of solar eclipses according to the Pauliśa Siddhānta. I see no reason for rejecting this statement; for although the text of the chapter itself does not refer to the Pauliśa Siddhānta, it most probably actually bases on the teaching of this latter work, since the two other chapters (VII and VIII) which teach the theory of solar eclipses certainly refer to the Sūrya and Romaka Siddhāntas. From this again it follows with great probability that also the sixth chapter, which treats of lunar eclipses, represents the teaching of the Pauliśa Siddhānta; and if so, then likewise the fifth chapter merely designated as Śaśidarśanam. These assumptions are confirmed by the fact that these three chapters treat only of the calculation of eclipses in the narrower sense, to the exclusion of all preliminary operations, such as the ascertainment of the mean and true longitudes etc. of sun and moon, so that an introductory chapter setting forth those latter topics is required. Now, a chapter of this nature is supplied by the third one of the Pañchasiddhāntikā which gives rules for finding the mean and true places of the sun (and of the moon?) and for similar operations, and

which, in its colophon at least, is said to represent the teaching of the Pauliśa Siddhânta. The relation, however, of the third chapter to the one immediately preceding is puzzling. The second chapter is, in the colophon, merely designated as "nakshatrâdichchheda," but its contents comprise firstly a rule or set of rules for finding the mean (and perhaps also true?) places of the moon (stanzas 1—7), and, secondly, a set of rude, approximative rules for calculating the length of the day at any time of the year, the length of the shadow of the gnomon, and, from the latter, the mean place of the sun, and the lagna (and vice versâ; stanzas 8—13). The chapter concludes with the words "This is the (calculation of the) shadow according to the concise Vâsishṭha Siddhânta." The question now is, whether this whole chapter has to be viewed as epitomizing the Vâsishṭha Siddhânta, or whether that work is represented only by its latter part. The rules contained in stanzas 8—13 are of a very rough character, and can, for that reason, hardly come from the Pauliśa Siddhânta; their character, on the other hand, agrees very well with the criticism passed by Varâha Mihira, in the first chapter, on the imperfections of the Vâsishṭha Siddhânta. It is more difficult to arrive at a conclusion regarding the rules embodied in stanzas 1—7. If they do not belong to the Vâsishṭha Siddhânta, it would follow that the Pañchasiddhântikâ, which after all promises to render us acquainted with the doctrines of all the five Siddhântas, however imperfect some of them may be, does not even inform us how the place of the moon is calculated according to the Vâsishṭha Siddhânta, while it yet gives the corresponding rules from the, certainly not more advanced, Paitâmaha Siddhânta, very concisely indeed but yet with sufficient fulness. On the other hand there appears to be some reason for tracing the rules to the Pauliśa Siddhânta. The third chapter, which, as we have seen above, we may connect with the Pauliśa Siddhânta with a very high degree of probability, gives in stanzas 1—3 the required rules for finding the mean and true places of the sun, and then continues, in stanzas 4—9, to give certain rules about the moon. Now these rules have unfortunately remained obscure to us; but yet so much appears certain that they are somehow connected with the rules concerning the moon given in the former half of chapter II, constituting, as it seems, a kind of continuation, or more accurate version of the latter. But again, on this latter hypothesis no reason is apparent why the two sets of rules should be separated from each other by the altogether heterogeneous matter treated of in the latter half of chapter II. I therefore see myself obliged to leave this point undecided, and only wish to suggest, as a third not impossible alternative, that the method for calculating the places of the moon which is set forth in chapter II belonged, in its essential features at least, to the Pauliśa as well as to the Vâsishṭha Siddhânta.

and that stanzas 8-13 of the third chapter add certain details which were peculiar to the former of the two Siddhântas. It is greatly to be regretted that the introductory stanza of chapter II, which possibly would throw some light on the position of the chapter, has remained altogether obscure to us.

There now remain for adjudgment only the first and the last chapters of the Pañchasiddhântikâ. The latter I shall discuss further on. The position of the former is altogether clear; it contains, subsequently to some introductory stanzas, a rule for calculating the ahargana according to the Romaka Siddhânta, an exposition of the principles according to which the intercalation of lunar months and the omission of lunar days are managed in the Paulîśa, Romaka and Sûrya Siddhântas, and finally a set of rules for calculating the so-called Lords of the year, month etc., which rules were most likely given in each of the three Siddhântas last mentioned.

The second question, which must be touched upon before we can review the teaching of the individual Siddhântas, is whether the Pañchasiddhântikâ represents the teaching of the five astronomical works, on which it is professedly based, with absolute accuracy, or rather allows itself certain modifications of the doctrines summarized. This question is one of considerable importance; for before we have settled it one way or other, we are unable to judge of the historical position of the five Siddhântas, and to compare the account, given of them by Varâha Mihira, with what we know about them from other sources. We have, in this part of our investigation, to occupy ourselves almost exclusively with the Sûrya Siddhânta, because that treatise is the only one of the five Siddhântas which has come down to our time, and thus allows of our comparing it with what Varâha Mihira tells us about the Sûrya Siddhânta as known to him. Now a cursory survey of those chapters of the Pañchasiddhântikâ which treat of the Sûrya Siddhânta shows at once that the treatise of that name known to Varâha Mihira agreed with the modern Sûrya Siddhânta in its fundamental features. The methods of the two treatises are essentially the same and, on the other hand, sufficiently different from those of the other Siddhântas summarized by Varâha Mihira, to ensure to the Sûrya Siddhânta in its two fold form a distinct position of its own. At the same time we cannot fail to notice that in certain points the teaching of the old Sûrya Siddhânta (by which name I shall, for shortness sake, designate the Sûrya Siddhânta known to Varâha Mihira) must have differed from the correspondent doctrines of its modern representative. If we, for instance, observe that the old Sûrya Siddhânta assigned to the mean diameters of sun and moon the values 32' 5" and 30' 54" (P. S. IX. 15. 16), while 32' 3."6 and 32' are the corresponding values according to the modern

treatise ; or if we notice the values assigned in XVII 1. 2 to the epicycles of the apogee which altogether differ from those stated in the modern *Sūrya Siddhānta* ; we are driven to the conclusion that in these and similar points the treatise used by Varāha Mihira really differed from the modern one known to us. For we are altogether unable to imagine any reason why Varāha Mihira should have changed, in the details referred to, the doctrines of the book which he aims at epitomizing.

There is however a series of other cases in which the decision is not quite so simple. While, as remarked above, the mathematical processes prescribed in the old *Sūrya Siddhānta* agree on the whole with those of the modern treatise, it at once appears that Varāha Mihira whose intention it is to write a *karāṇa* considers himself entitled to represent the teaching of his original in a somewhat condensed form, facilitating the quick despatch of the required astronomical calculations. What he *f. i.* says, in the first chapter, about the yuga of the *Sūrya Siddhānta*, clearly is an abbreviated statement of the corresponding doctrines of the old *Sūrya Siddhānta*, and we therefore have no reason to doubt of the old *Siddhānta*, as well as the modern one, having taught that 4320000 years constitute a great age, and that one thousand such great ages go to a kalpa. The fact is that for all the merely theoretical part of a *Siddhānta* there is no room in the *karāṇa*, and that hence the latter does all that is required if, instead of describing the great periods of the world, it states the smallest possible aggregate of years comprising an integral number of lunar months and natural days. So far we have no reason to hesitate in accepting Varāha Mihira's statements as a faithful, though somewhat modified, rendering of the meaning of the old *Sūrya Siddhānta* ; the question however assumes a somewhat different aspect when we compare the number of natural days contained, on the one hand, within the mahāyuga of the modern *Sūrya Siddhānta*, and, on the other hand, within the corresponding period according to Varāha Mihira. The modern *Sūrya Siddhānta* teaches that a mahāyuga of 4320000 years comprises 1593336 intercalary months and 25082252 omitted lunar days, whence it follows that the number of sāvana days contained within the same period amounts to 1577917828. Varāha Mihira on the other hand, following *his* *Sūrya Siddhānta*, states that a period of 180000 years comprises 66389 intercalary months and 1045095 omitted lunar days, so that a mahāyuga ($= 24 \times 180000$ years) consists of 1577917800 sāvana days, *i. e.* 28 days less than according to the modern *Sūrya Siddhānta*. Here it certainly appears possible that Varāha Mihira should have slightly diminished the number of the sāvana days of the mahāyuga, and implicitly the length of the solar year, in order to be able to reduce

that number, as well as the number of the years of the yuga, by twenty-four and thus to arrive at figures more easy to manipulate; all the more as the inaccuracy involved in that change would affect to an almost insensible degree only the comparatively short periods to which the rules of the *karāṇa grantha* are meant to be applied. But in spite of this undeniable possibility I am inclined to think that in the present case also Varāha Mihira proceeded with strict accuracy, and that his *Sūrya Siddhānta* actually assigned to the great yuga twenty-eight days less than the modern treatise does. For in addition to the general consideration that there are several other items in which the old and the new *Siddhāntas* differed beyond any doubt, we have in the present case two special reasons *viz.* firstly that it would have sufficed to diminish 1577917828 by four (instead of twenty-eight) in order to make it divisible by twenty-four; and secondly that the estimation of the length of the solar year implied in the statement of the old *Sūrya Siddhānta* agrees exactly with that value of the length of the Solar year that results from the elements of that *Paulīśa Siddhānta* about which Bhaṭṭotpala's commentary on the *Bṛihat Samhitā* and Prithūdaka Svāmin's commentary on Brahmagupta's *sphuṭa Brahma Siddhānta* furnish some information. As we shall see at once, Varāha Mihira's *Sūrya Siddhānta* agreed with that *Paulīśa Siddhānta* in several other points also, and it therefore is not improbable that the two *Siddhāntas* were at one also concerning the length of the solar year. If this is so, the most important item by which hitherto the *Sūrya Siddhānta* was considered to be distinguished from the *Paulīśa Siddhānta* (as reported by Bhaṭṭotpala etc.) would vanish; which clearly shows that an accurate investigation of the degree of strictness with which Varāha Mihira reproduces the doctrines of his *Siddhāntas* cannot be dispensed with.

Similar to the case just discussed is that of the mean revolutions of the planets, as reported, according to the *Sūrya Siddhānta*, in the 16th chapter of the *Pañchasiddhāntikā*. As appears from the notes to the translation and the latter part of this Introduction, the periods assigned to the mean revolution by the old *Sūrya Siddhānta* differed more or less from the corresponding values stated in the modern treatise. There, however, the hypothesis of Varāha Mihira having for some reason or other modified the elements of the work with which he had to deal seems altogether excluded. If he had chosen to state the length of the revolutions of the planets in the ordinary form *i. e.* by establishing periods within which the planets perform integral numbers of complete revolutions, he might possibly have had reason to manipulate the traditional numbers to a certain extent, so as to reduce them to more manageable terms. But in the case under discussion he follows another plan *viz.* of at first stating the time of one revolution in round numbers, and then directing

us to apply a certain correction, in order to make up for the inaccuracy involved in the employment of those round numbers. Now it is easy to see that, if Varāha Mihira's Sūrya Siddhānta had exhibited the same figures as the modern Siddhānta, the amount of the corrections would differ from that actually stated by him, and we therefore are entitled to conclude that regarding the revolutions of the planets also the old Sūrya Siddhānta actually differed from the modern one; a conclusion moreover made more acceptable by the circumstance that several of the values assigned to the mean revolutions by Varāha Mihira's Siddhānta agree with the teaching of the Paulīśa Siddhānta known to Bhaṭṭotpala, and with that of Āryabhaṭa.

That the difference, observed between the numbers of the natural days of the yuga as stated by the two Sūrya Siddhāntas, is due to a real discrepancy of the two books, is further confirmed by the rule given in Chapter X 2 and 4 for finding the mean place of the moon. This rule is based on the elements of the yuga as stated in chapter I, but for the sake of greater facility of calculation employs reduced numbers. Instead of multiplying the given ahargana by $\frac{2406389}{65746575}$ (the numerator of which fraction are the sidereal revolutions of the moon during the period of 180000 years, and the denominator the sāvana days comprehended within the same time), it directs us to employ the expression $\frac{900000}{24589506}$, and thereupon—in order to make up for the error involved in this substitution—to deduct from the mean place of the moon thus found $\frac{51''}{3120}$ for each revolution. In other words, Varāha Mihira is unwilling to allow to pass an error in the mean position which amounts to no more than one sixtieth of a second of space for each revolution. But if he, on the other hand, had purposely, for mere convenience of calculation, lessened the length of the mahāyuga by twenty-eight days, he would thereby have reduced the length of each sidereal month by about four hundredths of a second of time, which in its turn would have implied an error in the moon's mean place amounting to about one fiftieth of a second of space for each revolution. So that, while anxious to correct one small error, he would have allowed another greater one to pass; an assumption which we have absolutely no right or reason to make.

The investigation of special cases thus certainly favours the conclusion that the changes which the old Sūrya Siddhānta has undergone in Varāha Mihira's representation are purely formal, and that convenience of calculation is held by him to be a consideration of altogether secondary importance.

We therefore, and this is the most important conclusion to be drawn from the preceding enquiry, may hold ourselves entitled to look in the same light upon Varāha Mihira's rendering of the other Siddhāntas which we can

check neither by means of the originals nor with the assistance of modern recasts. There also we must hold Varāha Mihira to have closely followed the elements and methods of the authors of the Siddhāntas, and to have permitted himself only minor changes, such as facilitate calculation without affecting the fundamental character of the rules. General principles, enabling us to judge with certainty how far those changes may extend, can however not be laid down; we rather must judge each given case on its own merits. When we *f. i.* find that the yuga of the Romaka Siddhānta comprised, according to Varāha Mihira, only 2850 years, we may raise the question whether this yuga is the true yuga of the Romaka, or only represents a subdivision of the true yuga, analogous to the 180000 years of the Sūrya Siddhānta which, as we have seen above, must be considered as the smallest fraction of the mahāyuga with which the calculation of the ahargana can be effected. But we shall without much hesitation decide in favour of the former alternative, in the first place because the yuga of the Romaka Siddhānta is expressly called a yuga of the sun and moon, for the formation of which a comparatively small number of years was sufficient, and in the second place because Brahmagupta, in a passage to be quoted later on, testifies that the Romaka Siddhānta did not conform to the traditional views concerning the large periods of time. If, again, we find that according to the Pañchasiddhāntikā the Paulīśa Siddhānta made no use of yugas of any kind to the end of calculating the ahargana and the mean positions of the planets, but employed for those purposes a peculiar system of its own, we certainly must conclude that system to have been actually taught in the original Paulīśa Siddhānta, and not constructed, as indeed it might have been, by Varāha Mihira on the elements of the Paulīśa Siddhānta. For why, we must ask ourselves, should he have transformed in that way the elements of the Paulīśa Siddhānta rather than those of the other Siddhāntas which without any difficulty might have been thrown into the same form? And, to single out one further point, if we find that the Pañchasiddhāntikā gives a rule how to calculate, according to the Sūrya Siddhānta, the equation of the centre of sun and moon for any given anomaly, while it represents the Paulīśa and Romaka Siddhāntas as merely stating the amount of those equations for a certain series of anomalies, without teaching us how to calculate the equations for the intervening anomalies; we must again suppose that Varāha Mihira faithfully renders characteristic features of the original Siddhāntas as he found them; for if he had held the opinion (which as the writer of a karaṇa he indeed might have held) that the practical astronomer knows enough, if he can assign the equations of the centre for, let us say, each fifteen degrees of anomaly, he would no doubt not have given the general rule from the Sūrya

Siddhânta, but calculated from it the amounts whose knowledge he considered indispensable, and inserted them ready calculated in his text.

We therefore arrive at the conclusion that Varâha Mihira has in no case obliterated the characteristic features of the Siddhântas he had to deal with, and that whatever distinguishes those works from one another in the text of the Pañchasiddhântikâ really distinguished them in their original form. We may note in conclusion that there is one interesting circumstance which furnishes a kind of counterproof to this conclusion. According to VII. 1. and VIII. 9 the Paulîsa and Romaka Siddhântas calculated the parallax in longitude at a solar eclipse in exactly the same manner. Now Varâha Mihira accentuates this agreement of the two works by stating the rule each time in exactly the same words. But an author, who is so evidently desirous to mark the points in which the different authorities on which he draws are at one, may certainly be supposed to be no less scrupulous in stating the details in which they diverge.

After having thus cleared the way, I proceed to give short summaries of the doctrines of the five Siddhântas, beginning with that one which, owing to the existence of a modern recension, is best known, *viz.* the Sûrya Siddhânta.

According to I. 14 the Sûrya Siddhânta of Varâha Mihira taught that 180000 years contain 66389 intercalary months, and 1045095 omitted lunar days. The number 180000 is the twenty-fourth part of the years of a mahâyuga; if we therefore, for comparison's sake, multiply the figures given above by twenty-four, and deduce from them the number of the sâvana days of a yuga, we obtain 1577917800; while the corresponding figure for the modern Siddhânta is 1577917828. The length of the sidereal year resulting from these figures is $365^d 6^h 12' 36'' \cdot 56$ in the case of the modern, and $365^d 6^h 12' 36''$ in the case of the old Sûrya Siddhânta. The latter value exactly agrees with that which, according to Bhaṭṭotpala and others, was assigned to the solar year in the Paulîsa Siddhânta. Sûrya Sidh

What the old Sûrya Siddhânta taught about the mean motions of the sun and moon, is immediately apparent from the above statement concerning the nature of the yuga. The number of the moon's sidereal resolutions during the yuga is the same as in the modern Siddhânta; whence it follows that each revolution is a little shorter (the yuga of the old Siddhânta counting twenty-eight days less than that of the modern one). Rules how to calculate the mean positions of the sun and moon are given in chapter IX; they however call for no special remarks, as they follow immediately from the constitution of the yuga.—The duration of the revolution of the moon's apogee may

be derived without difficulty from stanzas 3 and 4 of the same chapter. From stanza 3 it follows that one revolution is performed in $3231^d 23^h 42' 16'' \cdot 76$; while the duration resulting from the elements of the modern Siddhânta amounts to $3232^d 2^h 14' 53'' \cdot 4$. And if, accommodating ourselves to the general Siddhânta practice, we determine the number of revolutions performed within one mahâyuga, we obtain 488219 for Varâha Mihira's Sûrya Siddhânta; while the modern Siddhânta gives 488203 only. We note that according to Âryabhata also the apogee performs 488219 revolutions within one mahâyuga.

From stanza 5 of the same chapter we learn that the old Sûrya Siddhânta agreed likewise with Âryabhata in reckoning 232226 revolutions of the moon's node to one mahâyuga; while the modern Siddhânta counts 232228.—In estimating the greatest latitude of the moon at 270 minutes (stanza 6) the old Sûrya Siddhânta agreed with the modern one.

According to stanza 7 the old Sûrya Siddhânta assigned to the sun's apogee the longitude of eighty degrees. Âryabhata gives 78° only, and a calculation of the place of the apogee for the epoch of the Pañchasiddhântikâ, based on the elements of the modern Sûrya Siddhânta, gives about 77° . The Pañchasiddhântikâ says nothing about the revolutions of the apogees of the sun and planets, and it hence is possible that the old Sûrya Siddhânta was not yet acquainted with the theory held, on entirely insufficient grounds, by the modern treatise, and modern Hindû astronomers in general, that the apogees of the sun and the planets perform a certain number of revolutions within a mahâyuga or kalpa. On the other hand it might be supposed that Varâha Mihira, although acquainted with that doctrine, yet confined himself to stating the places which the apogees occupied at his time, since so much is sufficient for the purposes of a karaṇa-writer.—The rules for finding the true places of the sun and moon, which are given in stanzas 7 and 8, are analogous to those of the modern Sûrya Siddhânta, with the one important difference that, while the latter assumes epicycles of different size for the even and odd quarters of the revolution of the two bodies, Varâha Mihira's Sûrya Siddhânta knows of one epicycle only for the sun as well as for the moon. The rules for finding the true motion, etc. given in stanzas 13 and 14 agree with those of the modern work.

The rules for calculating solar and lunar eclipses agree with the modern rules as far as general methods are concerned, but at the same time show many deviation in details; so *f. i.* in the calculation of the parallax in solar eclipses. Some of these rules we have, moreover, not been able to elucidate to our full satisfaction.

The mean motions of the planets (apart from sun and moon) are given in chapter XVI. The following statement shows the numbers of complete revolutions during one mahâyuga according to the old and modern Sûrya Siddhântas.

| | Old Sû. Si. | Modern Sû. Si. |
|---------|-------------|----------------|
| Mercury | 17937000 | 17937060 |
| Venus | 7022388 | 7022376 |
| Mars | 2296824 | 2296832 |
| Jupiter | 364220 | 364220 |
| Saturn | 146564 | 146568 |

The two Siddhântas thus agree concerning Jupiter only, and disagree therein from Âryabhata, according to whom Jupiter's revolutions amount to 364224 in one mahâyuga. The old Sûrya Siddhânta agrees with Âryabhata and the Paulîsa Siddhânta (according to Bhaṭṭotpala), as far as Venus, Mars and Saturn are concerned, while it agrees with the Paulîsa Siddhânta only concerning Mercury and Jupiter.

The positions of the apogees and the dimensions of the epicycles of the apsis and the conjunction are given in XVII, 1—3. It will be observed that, as regards the numbers indicating the size of the epicycles of the apsis of Venus and Saturn, the translation diverges from the corrected text given by us. The manifestly corrupt text was at first emendated on the basis of the dimensions stated in the modern Sûrya Siddhânta, the hypothesis of the agreement of the two Siddhântas in this detail being resorted to in the absence of evidence decidedly favouring any other assumption. But I afterwards discovered that such evidence exists. The statements which Brahmagupta in his Khandakhadyakakaraṇa makes about the places of the apogees and the dimensions of the epicycles agree with those made in the sixteenth chapter of the Pañchasiddhântikâ, in all those details in which the text of the latter work needs no emendation, and it therefore may be presumed that the agreement extended also to the epicycles of Venus and Saturn. And examining the traditional text of the Pañchasiddhântikâ from this point of view, we find that instead of the 'Surâs' of stanza 1 we have to read not 'śarâs' but 'svarâs' and that the 'trimsâḥ' is correct without any further addition. It is true that thus the Âryâ remains defective; but the word, or words, missing were most probably expletive rather than essential to the sense. Brahmagupta maintains his karaṇa to be founded on Âryabhata, or at any rate to give re-

sults equal to those to be derived from *Āryabhaṭa* ;* it is then a somewhat curious circumstance—into the discussion of which I cannot enter in this place—that the dimensions of the epicycles and the positions of the apogees assumed in the *Khaṇḍakhādyaka* (as well as in the sixteenth chapter of the *Pañchasiddhāntikā*) differ, all of them, more or less from those recorded in the *Laghu Āryabhaṭīya*.†

The method, taught in chapter XVII, of calculating the equations of the apsis and of the conjunction, agrees on the whole with that prescribed in the modern *Sūrya Siddhānta*, although there are several divergences in details. Peculiar are the special rule given for Mercury in stanza 10, and the correction to be applied to Venus' place according to stanza 11. The statements as to the distance from the sun at which the planets become visible differ to some extent from those made in the modern *Siddhānta*; so also the greatest latitudes of the planets given in stanzas 13 and 14.

An omission which might make us suppose that the chapter as given in our Manuscripts is not complete is that nothing whatever is said about the places of the planets' nodes.

Paitāmaha Siddhānta.

We next turn to the *Paitāmaha Siddhānta* which indeed has not come down to our time, but whose teaching throughout agrees with that of a well known section of Hindū astronomical literature.

Of this *Siddhānta* there treats only one very short chapter, of the *Pañchasiddhāntikā viz.* the twelfth one; but its five stanzas manifestly suffice to reproduce everything of importance contained in that very primitive treatise. The *Paitāmaha Siddhānta*, known to *Varāha Mihira*, represents Hindū Astronomy as not yet affected by Greek influences,‡ and thus belongs to the same category as the *Jyotisha-Vedāṅga*, the *Garga Saṃhitā*, the *Sūryaprajñapti* and similar works. From what *Varāha Mihira* says about its contents, we might almost identify it with the *Jyotisha Vedāṅga*. The yuga on which the calculations of the *Paitāmaha Siddhānta* base is the well known quinquennial one.

* *Brahmagupta's Khaṇḍa-khādyaka* begins with the following stanza

प्रणिपत्य महादेवं जगदुत्पत्तिस्त्यतिप्रलयहेतुं ।

वक्ष्यामि खण्डखाद्यकमाचार्यार्थभटतुल्यफलम् ॥

† It is also worthy of notice that *Āmaśarman*, one of the Commentators of the *Khaṇḍakhādyaka*, quotes some stanzas from a *Paulīśa tantra* which make the same statements about the dimensions of the epicycles as the *Khaṇḍakhādyaka* itself, and, moreover, seems generally to treat the doctrines of *Āryabhaṭa* and the *Paulīśa* as equivalent.

‡ As already pointed out by me in my paper on the *Jyotisha-vedāṅga*, *Journal of the Asiatic Soc. of Bengal* 1878.

which consists of five solar years of 366 days each, and contains sixty solar months, sixty-two synodical months, and sixty-seven so-called *nākshatramonths* i. e. sidereal revolutions of the moon. The beginning of the yuga is marked by a conjunction of the sun and moon at the first point of the *nakshatra* *Dhanishṭhâ*. The duration of the longest day of the year amounts to eighteen *muhûrtas*, that of the shortest to twelve *muhûrtas*; in the intervening periods the days increase or decrease by the same daily quantity.—The *Paitāmaha Siddhânta* refers to two points only which appear not to be mentioned in the *Jyotisha Vedāṅga*, as far as I have hitherto succeeded in making out the meaning of that difficult treatise. It, in the first place, gives a rule for calculating the so called *vyatipâta yogas* (st. 4); and in the second place, fixes a period from which the quinquennial yugas are to be counted. In st. 2 *Varâha Mihira* directs us to deduct two from the *Sâka* date, and to divide the remainder by five; which implies that a new yuga is supposed to begin with the third year of the *Sâka* Era, or two *Sâka* elapsed.

Whether this direction is due to *Varâha Mihira* only, or was already contained in the *Paitāmaha Siddhânta*, may be considered doubtful; the latter alternative, however, appears to be more probable, as *Varâha Mihira*, if in any way adding to—or rendering more definite—the teaching of the *Paitāmaha Siddhânta*, would most likely have adapted it to the same initial date as the other *Siddhântas*, viz. 427 *Sâka*.

The *Paitāmaha (Brâhma) Siddhânta* known to *Varâha Mihira* has thus to be distinguished from the *Brahma Siddhânta* on which *Brahmagupta's Sphuṭa Siddhânta* is based. That *Brâhma* or *Paitāmaha Siddhânta* is a short treatise in prose, forming part of the *Vishṇudharmottara-Purâṇa*, and belonging altogether to the modern phase of *Hindû Astronomy*. The number of *Brahma Siddhântas*, known at present, thus amounts to four, viz. the *Paitāmaha Siddhânta* summarized in the *Pañchasiddhântikâ*, the *Paitāmaha Siddhânta* forming part of the *Vishṇudharmottara*, the *Sphuṭa Brahmasiddhânta* by *Brahmagupta*, and that *Brahma Siddhânta* whose more ordinary name is *Sâkalya Siddhânta*.

There now remain the *Romaka*, *Pauliśa* and *Vasishṭha Siddhântas*, for the teaching of none of which we have any other source of importance but the *Pañchasiddhântikâ*. I begin with the first mentioned of these three treatises.

The fifteenth stanza of the first chapter shortly describes the nature of the yuga employed by the *Romaka Siddhânta*. The yuga is called 'one of the sun and moon' i. e. a *lunisolar* one, and said to comprise 2850 years, Romaka

which period is further stated to contain 1050 adhimâsas and 16547 praiśā. *i. e.* tithipralayas, omitted lunar days. The above numbers of years and intercalary lunar months allow of being reduced by 150, and we thus find in the opinion of the author of the Romaka, 19 solar years exactly contain seven intercalary months, or—if we take the entire sum of months—the 19 solar years comprise 235 synodical lunar months. The yuga of the Romaka is thus evidently based on the so-called Metonic period, named after the Athenian astronomer Meton who, about 430 B. C., showed the means of improving the Greek Calendar of his time by the assumption of 19 tropical years comprising 235 synodical months.—That the Romaka Siddhânta, instead of making use of the simple Metonic period, employs its one hundred and fiftieth multiple, has a reason not difficult to discern. The author of the Romaka, although manifestly borrowing his fundamental period from the Greeks, at the same time wished to accommodate himself to the Indian fashion of calculating the sum of days which has elapsed from a given epoch (the so-called *ahargana*) by means of a cyclic period comprising integral numbers of years, lunar months and natural days. Now the simple Metonic period does not represent an aggregate of the nature required, neither if we—with Meton himself—estimate the length of the tropical year at $365\frac{5}{13}$ days, nor if we avail ourselves of the more accurate determinations by which later Greek astronomers improved on the work of Meton, and it therefore becomes requisite to employ a multiple. What the multiplying number is to be, of course depends on the value assigned to the length of the year, and we therefore have to ascertain the opinion held on this point by the author of the Romaka. The data supplied in stanza 15 enable us to do so without difficulty. For if we multiply the 2850 years of the Romaka yuga by 12 (in order to find the number of corresponding solar months), add the 1050 adhimâsas (whereby we obtain the number of synodical lunar months), multiply by 30 (so as to obtain the lunar days), and finally deduct the 16547 tithi pralayas, the final result amounts to 1040953 natural days; which being divided by 2850 (the number of the years of the yuga), we obtain for the length of one year $365^d 5^h 55^m$. But in order to form an aggregate of years which contains an integral number of days and at the same time is divisible by nineteen, $19 \times 50 = 2850$ must be taken.

Whence the above determination of the year's length was adopted by the author of the Romaka, there cannot be any doubt. The year of the Romaka is, down to seconds, the tropical year of Hipparchus or, if we follow that of Ptolemy who accepted the determination, considerably faulty as it was made by his great predecessor.

The rule for calculating the ahargana according to the Romaka (I. 8—10), and so likewise the rules for finding the mean places of the sun and the moon (VIII. 1. 4) immediately follow from the constitution of the yuga, and have been elucidated in the notes to the translation. The length of the periodical month would, according to the Romaka, amount to $27^d 7^h 43' 6.3''$.

To the apogee of the sun the longitude of 75° is ascribed in VIII. 2. —The apogee of the moon and its periods of revolutions are not, in the usual Indian style, treated apart from the moon's motion; the 8th chapter (stanza 5) rather contains a rule for calculating the moon's position with regard to her apogee directly *i. e.* without any preliminary separate calculation of the apogee's place. The kendra mentioned there is the moon's anomaly, and the rule implies that the anomaly revolves 110 times within 3031 days, in other words that the moon returns to her apogee, or performs one anomalistic revolution, in $27^d 13^h 18' 32''$. 7.

By deducting the longitude of the sun's apogee from the mean longitude of the sun we find the sun's anomaly, and may then proceed to calculate his true longitude. For the latter process the Romaka Siddhânta however does not supply any general rule, enabling us to deduce the required equation of the centre for any given anomaly; but contents itself with stating the amounts of the equation from 15 to 15 degrees of anomaly. These amounts are stated in VIII. 3, and it is of interest to note that they agree very closely with the corresponding amounts given by Ptolemy. The greatest equation of the centre, which according to the modern Sûrya Siddhânta amounts to $2^\circ 10' 13''$, and which in no other Hindû text book known to me greatly differs from this latter value, according to the Romaka amounts to $2^\circ 23' 23''$, while Ptolemy assigns to it the value of $2^\circ 23'$; and also the equations for the smaller anomalies show a pretty close agreement, as appears from the following tabular statement

| Degrees of Anomaly. | 15 | 30 | 45 | 60 | 75 | 90 |
|---|------------|-------------------|--------------------|-------------------|-------------------|--------------------|
| Equation of centre according to the Romaka. | $34' 42''$ | $1^\circ 8' 37''$ | $1^\circ 38' 39''$ | $2^\circ 2' 49''$ | $2^\circ 17' 5''$ | $2^\circ 23' 23''$ |
| According to Ptolemy. | | $1^\circ 9'$ | | $2^\circ 1'$ | | $2^\circ 23'$ |

The values quoted from Ptolemy are those given by him for the quadrants of the apogee. The Romaka Siddhânta apparently makes no distinction of quadrants, but employs the same equations indiscriminately for all.

In an analogous manner stanza 6 states the moon's equations of centre from 15 to 15 degrees of anomaly. These equations do not agree closely with the corresponding ones of Ptolemy, according to whom the greatest equation amounts to $5^{\circ} 1'$.—The length of the revolution of the moon's node amounts, according to VIII. 8, to $6796^d 7^h$, in pretty close agreement with Ptolemy's determination of the same quantity, viz. $6796^d 14^h$ etc.—Concerning the greatest latitude of the moon we have two conflicting statements implied in VIII. 11 and VIII. 14, provided the interpretation of the stanzas given in the translation be right. According to the former it amounts to $240'$; according to the latter to $270'$, which is the value ordinarily met with in Hindû astronomical works. Regarding the explanation given in the translation of stanza 14 I have to remark that it is an attempt on the part of my collaborator to connect the rule with the usual estimation of the moon's greatest latitude, while the fraction $\frac{21}{9}$, if its denominator be taken as the reduced Radius, would strictly lead back to a greatest latitude of $280'$. If different values should be ascribed to the same quantity in one and the other book, might *primâ facie* appear inadmissible; but it is by no means impossible that in some of the older Siddhântas there were incorporated empirical data borrowed from various sources, the rationale of which was not understood.

Stanza 13 gives $30'$ and $34'$ for the mean measure of the diameters of the sun and moon respectively, and st. 15 gives the ordinary Indian rule for finding the true diameters from the mean diameters and the true and apparent motions.

The greatest parallax is, as in Indian astronomy generally, supposed to be equal to the mean motion during four *nâdikâs*; hence the rule given in st. 9 for calculating the parallax in longitude, the result being the difference of the parallaxes of the sun and the moon.

The parallax in latitude is calculated on the same principle (stanza 14), the result however not giving the difference of the solar and the lunar parallaxes, but merely the latter one, the solar parallax being neglected. The inaccuracy in the preliminary determination of the zenith distance of the moon in nonagesimal is noted in the translation.—The rule for calculating the duration of the eclipse, after the true latitude has been ascertained (st. 16), is the usual one.

What remains unexplained of the Romaka Siddhânta are, principally, the different *kshepa*-quantities met with in the rules for finding the apparent places (Chapter I), and the mean places of sun, moon, etc. (Chapter VIII).

of course, are intended to enable us to start in our calculation from the epoch of the Pañchasiddhântikâ (or of *the*, or *some*, Romaka-Siddhânta, about which see below), and their elucidation would probably lead to some interesting results. It will be observed that the rule for calculating the ahargana professes to be adapted to the meridian of Yavanapura, while the rules for finding the places of the sun, moon etc. refer to the meridian of Ujjayinî.* The difference in longitude of those two places is stated by Varâhamihira—following the Paulîsa Siddhânta as it appears—in III. 13.—A further reference to the Romaka which has remained obscure to us seems to be made in III. 73.—Whether any of the rules concerning the planets which are given in the last chapter base on the Romaka Siddhânta, is doubtful.

From this short summary of the contents of the Romaka Siddhânta I pass on to the consideration of its authorship and time of composition, coupling therewith—for reasons which will appear later on—an enquiry as to the date of the Pañchasiddhântikâ itself.

Hitherto it has been generally held, on the authority of Colebrooke and Bhâu Dâjî, that the original Romaka Siddhânta was composed by Śrîsheṇa; an opinion which I myself, when writing my paper on the Pañchasiddhântikâ (Journ. Asiat. Soc. of Bengal) was not prepared to abandon entirely, although then already certain considerations led me to suggest that Śrîsheṇa's work might after all have been a mere recast of an older treatise of the same name. This latter view I now feel inclined to set forth as the only true one.

The authorities for Colebrooke's and Bhâu Dâjî's opinion were Brahmagupta and his commentator Prithûdaka Svânin. Brahmagupta, in a considerable number of passages of his Sphuṭa Siddhânta, refers to Śrîsheṇa by name, and in connexion with those passages his commentator repeatedly remarks that Śrîsheṇa was the author of the Romaka Siddhânta. And in one passage at least Brahmagupta himself mentions Śrîsheṇa in connexion with the Romaka Siddhânta. That passage which is found in the Tantra-parîkshâdhyâya (the 11th chapter of the Sphuṭa Siddhânta) was discussed by me in the paper referred to above (pp. 290 ff.), but owing to the very corrupt form in which the Manuscripts of the Sphuṭa Siddhânta exhibit its text I did not at that time fully understand it, so that the meaning of just its most

* The truth of this remark of course depends, in the first place, on the correctness of the emendation in VIII. 5 owing to which we have substituted स्तगमे वन्त्याम् (read so in the text, instead of स्तगमवन्त्याम्) for the °स्तगमवद्यां of the Manuscript; and in the second place, on the assumption that the clause "at sunset, at Avanti" has to be connected generally with the rules given in stanzas 1—5. But both this assumption and the emendation appear to me well founded.

important clause escaped me, as it seems to have escaped Colebrooke and Bhāu Dāji. The text of the passage, as appearing in Colebrooke's manuscript (now in the India Office Library), runs as follows:—

श्रीशेषविष्णुचंद्रप्रद्युम्नार्यभट्टनालसिंहानां । १
 ग्रहणादिविस्वादात् प्रतिदिवसं सिद्धमज्ञत्वम् । २
 युक्त्यार्यभट्टोक्तानि प्रत्येकं दूषयानि योज्यानि । ३
 आयेनप्रभृतीनां कानिचिदन्यानि वक्ष्यामि । ४
 आर्यान्पूर्वगणांको मध्यादिदृष्ट्युच्चं दूषयानि च । ५
 कुजबुधशार्धवृहस्पतिसितशीघ्रसनिश्चरान् मध्यान् । ६
 युगयातवर्षेभ्यश्चान्वान्विष्टान्विजयनंदिकृतपादान् । ७
 मंदोच्च परिधिपातान्दृष्टीकरणाद्वार्यभट्टात् । ८
 श्रीपेलेन गृहीत्वा रक्षोच्चरोमककृतकथः । ९
 एतानेव गृहीत्वा वासिष्ठो विष्णुचंद्रौ । १०

The other Manuscripts of the *Sphuṭa Siddhānta* known to me (one belonging to the Bombay Government; one, a modern copy, in the library of the Benares College; and one in the Royal Library of Berlin) have some important different readings. They all read in line 1 लाट° instead of लाल° and in line 5 लाटासूर्य° instead of आर्यान्सूर्य°. In line 7 the Ben. MS. reads वाशिष्ठाद्विज्ञानं, the Berlin MS. has वाशिष्ठाच्चंजयनंदिकृतपादान्; and the Bom. MS. वसिष्ठाभूनेयुगयातकृतपादात्. In line 8 the Bom. and Ben. MSS. read परिधिपातस्यदृष्टीकरणाद्वार्यभट्टात्. Line 9 runs in the Berlin MS. एतानेव गृहीत्वा चंद्ररक्षोच्चरोमकः कृतः कथा. The Ben. MS. reads गृहीत्वा रक्षोच्चरोमककृतः कथा, and the Bom. MS. गृहीत्वा रक्षोच्चरोमकात् कृतः कथा. In line 10, instead of वासिष्ठो the Ben. MS. has विशिष्ठो, the Bom. MS. विहितो (not to mention less important differences).

The general purport of this passage is clear. It is meant as a criticism of the performance of Śrīsheṇa, who in composing his astronomical text book borrowed rules and processes from various sources, and combined them into an incongruous whole. Leaving aside for the present the second half of line 7, and line 10, we may—emendating the text as given above with the help of the *varietas lectionis*—render the passage as follows.

‘From the fact that Śrīsheṇa, Viṣṇuchandra, Pradyumna, Āryabhaṭa, Lāṭa, and Siṃha contradict one another regarding eclipses and similar topics, their ignorance is proved daily. The criticisms which I (in the preceding part of the chapter) have passed on Āryabhaṭa are, with the requisite modification to be applied to the doctrines of each of those teachers as well. I will however make some further critical remarks on Śrīsheṇa and others.

Śrīsheṇa took from Lāṭa the rules concerning the mean motions of the sun and moon, the moon's apogee and her node, and the mean motions

Mars, Mercury's Sighra, Jupiter, Venus' Sighra and Saturn; from — — the elapsed years and revolutions of the yuga; from Âryabhaṭa the rules concerning the apogees, epicycles and nodes, and those referring to the true motions of the planets; and thus — — —'

Here we are confronted by the latter half of line 9, which seems to state that thus the Romaka (Siddhânta) was composed (kṛitaḥ) by Śrīsheṇa. But this would leave unexplained the last word of the line which three Manuscripts give in the form 'kanthâ.' Keeping therefore this latter reading, and substituting (with the Berlin and Bom. MSS.), 'ratnochchayo' for the four aksharas preceding 'Romakaḥ,' I translate 'and thus the Romaka (Siddhânta) which was (or 'is') a heap of jewels (as it were) has, by Śrīsheṇa, been made into a patched rag (as it were).'

In other words: Śrīsheṇa incorporated into the old genuine Romaka Siddhânta elements borrowed from various heterogeneous sources, and thereby spoilt it, making it look like a piece of cloth, or dress, made up of various patches.

The Romaka Siddhânta going under Śrīsheṇa's name was thus not the original one, but merely a recast of it, into which new matter borrowed from different astronomical writers had been introduced. This is neither improbable in itself, nor altogether destitute of collateral proof. For if we compare the information concerning Śrīsheṇa's Romaka Siddhânta, given by Brahmagupta, with what we now know about the Romaka Siddhânta epitomized by Varāha Mihira, certain differences between the doctrines of the two works present themselves at once. I here confine myself to two points, the consideration of which does not necessitate a reference to any other passage from the Sphuṭa Brahma Siddhânta but the one quoted above. The first point of disagreement is that Śrīsheṇa, according to Brahmagupta, borrowed his rules for the spasṭīkaraṇa i. e. for the calculation of the true places of the planets, from Âryabhaṭa. Now Âryabhaṭa's rules are known to us from the Laghva-âryabhaṭīya, and we observe that they agree in all essential points with the corresponding rules of the Sûrya Siddhânta, specifying, as the latter work does, the dimensions of the paridhi—epicycle of each planet, and teaching how the equation of the centre is to be calculated trigonometrically for any given anomaly. Varāha Mihira's Romaka Siddhânta on the other hand, as we have seen above, makes no mention of epicycles, does not in fact give any generally applicable rule for calculating the equation of the centre, but merely states in a tabular form the equations, howsoever calculated, for each fifteenth degree of the anomalies of sun and moon. That Romaka Siddhânta therefore manifestly had not borrowed its rules from Âryabhaṭa, and

hence cannot be identified with Śrīsheṇa's work. On the other hand it is quite intelligible that Śrīsheṇa, who appears to have followed the old Romaka Siddhānta as far as the mean motions of the planets are concerned, should have borrowed the rules for calculating the true places—which his principal authority was unable to supply—from the work of Āryabhaṭa. A second argument may be drawn from what, in line 7 of the extract quoted above from Brahmagupta, is said about Śrīsheṇa having borrowed from some other work (apparently some Vasishṭha Siddhānta) his theory as to the elapsed years and revolutions of the yuga. Judging from the expressions made use of in that place and from the context in which it stands, Śrīsheṇa's views about the yuga must have been akin to those generally held in the Siddhāntas on that point, the yuga being a vast period of time comprising integral numbers of complete revolutions of all the planets. But as we have seen above, the yuga employed in the old Romaka Siddhānta was an altogether different one, of a strictly lunisolar character and hence consisting of a comparatively moderate number of years. When, therefore, Brahmagupta, in the first chapter of the Sphuṭa Siddhānta, animadverts on the non-traditional character of the Romaka Siddhānta,* he manifestly does not refer to the recast by Śrīsheṇa in whose hands the Romaka Siddhānta had assumed a more orthodox form, but to the genuine Siddhānta, which at Brahmagupta's time was no doubt still in existence and duly distinguished from Śrīsheṇa's treatise.

We next have to consider the bearings of a date which, in the first chapter of the Pañchasiddhāntikā, is mentioned in connexion with the Romaka Siddhānta. Stanzas 8—10 which give a rule for calculating the ahargaṇa (*i. e.* the sum of civil days which have elapsed from an initial epoch up to a given date) direct us first to deduct 427 from the number of the current Saka year, which means that the initial epoch of the calculation is 427 Śaka. It then proceeds to explain the details of the calculation of the ahargaṇa, and closes with the words 'this is the ahargaṇa in (or, according to) the Romaka Siddhānta.'

That this date—427 Śaka—is mentioned in the Pañchasiddhāntikā, has been known to scholars since a considerable time. The astronomers of Ujjayinī who furnished to Dr. William Hunter the list of astronomers with their dates, published by Colebrooke (*Algebra* p. XXXIII), gave 427 Śaka as the time of (their second) Varāha Mihira. Albeṭtinī refers to it as the date

of the *Pañchasiddhântikâ*. Bhâu Dâjî quotes the stanza from the *Pañchasiddhântikâ* as furnishing the epoch of the *Romaka Siddhânta*, adopted by Varâha Mihira also. (*Journ. Royal Asiat. Soc. New Series Vol. I*). Dr. Kern is inclined to look upon 427 Saka as marking the year of the birth of Varâha Mihira who, as appears from a passage quoted by Bhâu Dâjî, died in Saka 509.

All these views clearly have no further foundation than the passage of the *Pañchasiddhântikâ* about the calculation of the *ahargana*. The view that 427 Saka is the year of Varâha Mihira's birth we may set aside without hesitation. Dr. Kern was led to that hypothesis partly by the consideration that the *Pañchasiddhântikâ*, which in one place refers to Âryabhata's views, could hardly have been composed in 505 A. D. when Âryabhata—born in 476 A. D.—was only 29 years old. We now know—from Dr. Kern's edition of the *Âryabhatîya*—that Âryabhata composed his work in 499 A. D. already, so that he might very well have been quoted in a book written in 505 A. D. The other argument brought forward by Dr. Kern, *viz.* that Varâha Mihira died in 587, certainly goes some way to prove that the *Pañchasiddhântikâ* was not written in 505, but not that Varâha Mihira was born in the latter year. The text of the *Pañchasiddhântikâ* enables us at present to judge of the position of Varâha Mihira with regard to the date 427 Saka. From the chapters on the *Sûrya Siddhânta* it appears that Varâha Mihira considers that year to be the epoch of his *karaṇagrantha* from which all astronomical calculations have to start; for all the *kshepa* quantities involved in the different rules, given in those chapters for finding the mean places of sun, moon, and planets, can be accounted for satisfactorily on that basis. I have no doubt that also the *kshepa* quantities stated in the *Romaka* and *Paulîsa* Chapters admit of being explained on the same supposition, but unfortunately we have so far not succeeded in finding the clue to their right understanding. Now it would certainly be most satisfactory, if we could assume that the *Pañchasiddhântikâ* was composed in the very year which it selects for its astronomical epoch, or at any rate within a few years of that year; for as nearness of the epoch tends to facilitate all astronomical calculations and, at the same time, to minimize the inaccuracies resulting from the fact that *karaṇa* rules are often only approximatively correct, it is the interest and the practice of *karaṇa* writers to choose for their epoch a year, as little remote as may be from the time of the composition of their treatises. The positive statement, however, made by Âmarâja (as quoted by Bhâu Dâjî) about the date of Varâha Mihira's death does not favour such an assumption; and we moreover find that the deduction of 427 forms part of a rule which in the end is said to be 'in' or 'according to' the *Romaka Siddhânta*. This

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यस्माच्च रोमके ते स्मृतिबाह्यो रोमकस्तस्मात् ॥

of the *Pañchasiddhântikâ*. Bhâu Dâjî quotes the stanza from the *Pañchasiddhântikâ* as furnishing the epoch of the *Romaka Siddhânta*, adopted by Varâha Mihira also. (*Journ. Royal Asiat. Soc. New Series Vol. I*). Dr. Kern is inclined to look upon 427 Saka as marking the year of the birth of Varâha Mihira who, as appears from a passage quoted by Bhâu Dâjî, died in Saka 509.

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